**Memorandum**

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| **From:** Jeremy Walgrave, PE  Derek Schlea | **Date:** December 11, 2017 |
|  |
| **To:** Mike Trojan, MPCA | **CC:** Andy Erickson, HR Green, AES |
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**Subject:** Minnesota Stormwater Manual Updates – Wet Swales

1. Wet Swale Overview Page
   1. **Brief definition**

Wet swales occur when the water table is located very close to the surface or water does not readily drain out of the swale. A wet swale acts as a very long and linear shallow biofiltration or wetland treatment system. Wet swales do not provide volume reduction and have limited treatment capability. Incorporation of check dams into the design allows treatment of a portion or all of the water quality volume within a series of cells created by the check dams. Wet swales planted with emergent wetland plant species provide improved pollutant removal. Wet swales may be used as pretreatment practices. Wet swales are commonly used for drainage areas less than 5 acres in size.

**Function within the treatment train**

Wet swales provide limited water quality treatment and no volume control and are not recommended practices unless options for other BMPs are limited.

Wet swales are designed primarily as in-line systems for stormwater quality and typically are used in conjunction with other structural controls in the stormwater [treatment train](https://stormwater.pca.state.mn.us/index.php?title=Using_the_treatment_train_approach_to_BMP_selection). Wet swales may be used at various locations within a treatment train and can be used for pre-treatment, conveyance, and/or primary treatment.

* 1. **MPCA permit applicability**

One of the goals of this Manual is to facilitate understanding of and compliance with the [MPCA Construction General Permit (CGP)](https://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit), which includes design and performance standards for permanent stormwater management systems. These standards must be applied in all projects in which at least 1 acre of new impervious area is being created, and the permit stipulates certain standards for various categories of stormwater management practices.

When volume control is constrained at a site and other BMP options (e.g. constructed pond, media filter) are not feasible, a wet swale with check dams provides treatment for a portion or all of the water quality volume stored behind the check dams. For regulatory purposes, wet swales that incorporate check dams into their design fall under the “Infiltration / Filtration" category described in Part III.D.1. of the [MPCA CGP](https://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit). If used in combination with other practices, credit for combined stormwater treatment can be given. Due to the statewide prevalence of the MPCA permit, design guidance in this section is presented with the assumption that the permit does apply. Although it is expected that in many cases the wet swale will be used in combination with other practices, standards are described for the case in which it is a stand-alone practice.

The following terms are thus used in the text to distinguish various levels of wet swale design guidance:

**REQUIRED**: Indicates design standards stipulated by the MPCA CGP (or other consistently applicable regulations).

**HIGHLY RECOMMENDED**: Indicates design guidance that is extremely beneficial or necessary for proper functioning of the wet swale, but not specifically required by the MPCA CGP.

**RECOMMENDED**: Indicates design guidance that is helpful for wet swale performance but not critical to the design.

There are situations, particularly retrofit projects, in which a wet swale is constructed without being subject to the conditions of the MPCA permit. While compliance with the permit is not required in these cases, the standards it establishes can provide valuable design guidance to the user. It is important to note that additional and potentially more stringent design requirements may apply for a particular wet swale, depending on where it is situated both jurisdictionally and within the surrounding landscape.

* 1. **Retrofit suitability**

The use of wet swales as a retrofit practice primarily depends on existing infrastructure and whether the invert or flowline of the wet swale outlet allow meeting design requirements.

* 1. **Special receiving waters suitability**

The following table provides guidance regarding the use of wet swales in areas upstream of special receiving waters. This table is an abbreviated version of a larger table in which other BMP groups are similarly evaluated. The corresponding information about other BMPs is presented in the respective sections of this Manual.

**Summary of design restrictions for special waters.**Link to this [table](https://stormwater.pca.state.mn.us/index.php?title=Design_restrictions_for_special_waters)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **BMP Group** | **Stormwater Management Category** | | | | |
| **A Lakes** | **B Trout Waters** | **C Drinking Water** | **D Wetlands** | **E Impaired Waters** |
| Wet Swale / Filtration | NOT RECOMMENDED due to poor phosphorus removal, combined with other treatments | RECOMMENDED | RECOMMENDED | ACCEPTABLE | RECOMMENDED for non-nutrient impairments |

* 1. **Cold climate suitability**

In cold climates, some special considerations are HIGHLY RECOMMENDED for surface systems like wet swales to ensure sustained functionality and limit the damage that freezing temperatures and snow and ice removal may cause.

For all BMPs it is HIGHLY RECOMMENDED that snow and ice removal plans including predetermined locations for stockpiling be determined prior to or during the design process. Wet swales cannot be used for significant snow storage areas as debris build-up and plant damage are likely to occur. Some snow storage is unavoidable when BMPs are adjacent to areas where snow removal is required. It is critical that the property owner and snow and ice removal contractor have identified other areas for large scale snow storage.

[Plant selection](http://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists) is critical to ensure that the damaging effects of snow and ice removal do not severely impact plantings or seedings. Even a small amount of snow storage can break and uproot plants requiring additional maintenance in the spring. Woody trees and shrubs should be selected that can tolerate some salt spray from plowing operations.

* 1. **Water quantity treatment**

Wet swales are not typically a primary practice for providing water quantity control. They are normally either designed off-line using a flow diversion or configured to safely pass large storm flows. In limited cases, wet swales may be able to accommodate the channel protection volume, Vcp, in either an off- or on-line configuration, and in general they can provide some (albeit limited) storage volume. Wet swales can help reduce detention requirements for a site by providing elongated flow paths and longer times of concentration, and provide very limited volumetric losses from infiltration and evapotranspiration. Generally, to meet site water quantity or peak discharge criteria, it is HIGHLY RECOMMENDED that another structural control (e.g., detention) be used.

It is HIGHLY RECOMMENDED that wet swales have a maximum slope of 1 percent.

**Warning**: It is REQUIRED that volume reduction practices, such as infiltration basins, are considered before filtration practices.

* 1. **Water quality treatment**

Wet swales provide some removal of sediment and associated pollutants through filtering and settling. Less significant processes can include evaporation, infiltration, transpiration, biological and microbiological uptake, and soil adsorption. Pollutant removal data for select parameters are provided in the table below.

* 1. **Limitations**

The following general limitations should be recognized when considering installation of wet swales:

* Nitrification of water may occur where aerobic conditions exist;
* Wet swales offer limited water quantity control;
* The potential for nuisance insects or odors exists;
* Water quality performance can change seasonally
* Wet swales are impractical in steep areas, because maintaining a constant water surface elevation or pool becomes too difficult;
* Wet swales are impractical in extremely flat areas, because the lack of gradient may cause excessive ponding and prevent positive drainage;
* Vegetation must be periodically trimmed to keep woody vegetation in check;
* A wet swale can erode during peak rainfall when water volume and velocity are high;
* Standing water in wet swales may foster mosquitoes, so vector control is recommended;
* Resuspension of sediment can occur during peak storm events; and
* Standing water causes water temperature to rise, which reduces oxygen in the water and negatively impacts nutrient removal.
  1. **Related Pages**

Swales for stormwater management

Design criteria for wet swales

Construction specifications for wet swales

Operation and maintenance of wet swales

References for wet swales

1. Wet Swale Design Criteria Page
   1. **Details and CADD images**

Use [this link](http://stormwater.pca.state.mn.us/index.php/CADD_images_for_individual_best_management_practices) to access .pdf diagrams of CADD drawings.

To see all filtration CADD images in a combined pdf,[click here](https://stormwater.pca.state.mn.us/index.php?title=File:All_filtration_cadd_images_combined.pdf)

* [Links to .dwg files for swales](https://stormwater.pca.state.mn.us/index.php?title=Links_to_.dwg_files_for_swales)
* Swale layout: [File:Swale Layout2 (1).pdf](https://stormwater.pca.state.mn.us/index.php?title=File:Swale_Layout2_(1).pdf)
* Typical grass channel cross-section without soil amendment: [File:MIDS Dry Swale Sections-SHEET 2.pdf](https://stormwater.pca.state.mn.us/index.php?title=File:MIDS_Dry_Swale_Sections-SHEET_2.pdf)
  1. **Major design elements** 
     1. **Physical feasibility initial check**
        1. Before deciding to use a swale practice for stormwater management, it is helpful to consider several items that bear on the feasibility of using such a device at a given location. This section describes considerations in making an initial judgment as to whether or not a wet swale practice is the appropriate BMP for the site. ***Contributing drainage area***

The *RECOMMENDED* maximum drainage area is typically 5 acres.

* + - 1. ***Site topography***

Unless slope stability calculations demonstrate otherwise, it is *HIGHLY RECOMMENDED* that swales be located a minimum horizontal distance of 200 feet from down-gradient slopes greater than 20 percent, and that slopes in contributing drainage areas be limited to 15 percent

* + - 1. ***Depth to groundwater and bedrock***

In general, there is no minimum separation distance required with stormwater wetlands. However, some source water protection requirements may dictate a separation distance if there is a sensitive underlying aquifer, which means that a [liner](http://stormwater.pca.state.mn.us/index.php/Liners_for_stormwater_management) might be required for portions of the wetland with standing water. A [Level 2](http://stormwater.pca.state.mn.us/index.php/Liners_for_stormwater_management" \l "Liner_specifications) liner is recommended.A field soil properties investigation is *HIGHLY RECOMMENDED*.

* + - 1. ***Karst topography***

If wet swales are used in karst areas, it is RECOMMENDED that maximum pool depths be 3 to 5 feet. Impermeable liners maybe needed. Geotechnical investigations are necessary in karst areas.

* + - 1. ***Soils hydrologic soil group mapping (link to “Design infiltration rates, in inches per hour, for A, B, C, and D soil groups”*** [***Table***](https://stormwater.pca.state.mn.us/index.php?title=Design_infiltration_rates)***)***

See [NRCS Web Soil Survey](https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) for hydrologic soil descriptions for the swale location. C and D soils are potentially suitable for wet swales. Infiltration abstractions are considered negligible in these conditions.

* + 1. **Practice and site considerations**

Several considerations are made in this section for the conceptual design of swales types. Further design guidance and specifications is made in the following sections.

* + - 1. ***Conveyance***

It is HIGHLY *RECOMMENDED* that the designer provides non-erosive flow velocities within the swale and at the outlet point to reduce downstream erosion. During the 10-year or 25-year storm (depending on local drainage criteria), discharge velocity should be kept below 4 feet per second for established vegetated channels. Erosion control matting or rock should be specified if higher velocities are expected.

* + - 1. ***Pretreatment***

If there is space for pretreatment prior to the swale it should be evaluated. See the [pretreatment](https://stormwater.pca.state.mn.us/index.php?title=Pretreatment) section for more information.

* + - 1. ***Anticipated flow***

Although local drainage criteria may require a certain frequency event be used in the design, it is HIGHLY RECOMMENDED that larger events be considered depending on the adjacent property and associated risks.

* + - 1. ***Grading***

#### Slope of swale

The longitudinal slope of a wet swale may vary from 0%-1%, and will affect the selection of swale type. It is HIGHLY RECOMMENDED that the design engineer also considers the expected watershed flow to be conveyed by the swale in making this preliminary determination of design alternate.

#### Swale bottom

It is HIGHLY RECOMMENDED that the swale bottom be no less than 3 feet wide and will be sized with the relative stage-dependent flow driven cross-sectional area in mind.

#### Side slopes

It is RECOMMENDED that the maximum side slopes within a swale do not exceed 3H:1V and will be designed with the relative stage-dependent flow driven cross-sectional area in mind.

#### Swale depth

Swale depth will be estimated based on the relative stage-dependent flow driven cross-sectional area.

#### Filtration considerations

The design engineer should review the results of the feasibility check to assist in the selection of swale type. An additional consideration includes watershed soil transport to the site. Watersheds with unstable soils or lack of vegetative cover (e.g., construction, farmland and highly impervious surfaces) can generate and transport excessive sediments to the swale that may affect filtration capacity. In these situations, pretreatment via sedimentation processes is HIGHLY RECOMMENDED. Construction of developments and roads, for example, significantly alter the parent state of native soils and therefore their hydrologic soil classification should be downgraded for feasibility study purposes.

* + - 1. ***Treatment***

Stormwater treatment in swales varies by design, relying on several functions. Organic and mineral sediments suspended in stormwater flows are deposited onto the swale bottom, depending on their size and mass as well as water retention time in a process termed sedimentation. Though swales generally do not detain or retain water for extended periods, this function can be enhanced through the use of check dams or weirs that hold back flows for a design period. A second function in pollutant removal is sorption of particulate matter via the swales soils and vegetation as it passes through the system. Wet swales also provide opportunity for plant uptake of pollutants.

Wet swales are not considered a volume reduction practice, though some volume reduction can occur through evapotranspiration.

* + - 1. ***Vegetation***

Vegetation plays a crucial role in swale treatment capacity, flow attenuation and as well as in providing stabilization of the swale itself (i.e., erosion control). It is HIGHLY RECOMMENDED that preference is given to robust native, non-clump forming grasses as the predominant plant type within the swale flow area. Care must also be taken to consider species selection in light of sun exposure duration/timing as well as soil moisture, ponding depth and ponding duration.

* + - 1. ***Landscaping***

Swales can be effectively integrated into the site planning process, and aesthetically designed as attractive green spaces planted with native vegetation. Because vegetation is fundamental to the performance and function of the swale, aesthetically chosen vegetation may only be possible on the surface tops of the swales.

* + - 1. ***Snow considerations***

Considering management of snow, the following are recommended

* Plan a plow path during design phase and tell snowplow operators where to push the snow.
* Plan for snow storage (both temporary during construction and permanent). Don’t plow into wet swales if possible.
* Snow storage could be, for example, a pretreatment forebay for snow melt.

For more information and example photos, see the section on [snow and ice management](http://stormwater.pca.state.mn.us/index.php/Cold_climate_impact_on_runoff_management#Snow_and_ice_management).

* + - 1. ***Safety***

Swales do not pose any major safety hazards. Potential hazards could occur from the steep side slope and rock checks of the swales if they are close to pedestrian traffic or roadways with no shoulders.

* 1. **Materials specification** 
     1. **Erosion control (MNDOT – product by velocity)**

The use of temporary erosion control materials is REQUIRED in the design and construction of all swale types to allow for the establishment of firmly-rooted, dense vegetative cover. The swale bottom and side slopes up to the 10-yr event should use robust erosion control matting that can resists the expected shear stresses associated with channelized flows. The matting should have a minimum life expectancy of three years. Upper banks of the swale slope should be protected by either similar matting or a straw/coconut blend erosion control blanket. See MNDOT specifications for guidance on selection of erosion control products.

* + 1. **Rock (MNDOT – specs)**
    2. **Weir (MNDOT – specs)**
    3. **Plants (MNDOT specs)**

Refer to the [vegetation](https://stormwater.pca.state.mn.us/index.php?title=Minnesota_plant_lists) section of the manual for selection of Minnesota native plants to be used in swales. Care must be taken to specify plants for their position in the system (swale bottom, side slopes and buffer). Preference towards robust non-clump forming grasses or sedges should be given to the swale bottom that can withstand flow forces as well as provide adequate filtration functions. It is also important to understand draw-down time not only within the channel itself, but in either in-situ soils or the filter media as plants have variable tolerance to the depth and duration of inundation as well as soil moisture period. Lastly, care should be taken to understand sun exposure requirements of various plants to ensure a robust, dense establishment of vegetative cover.

Open vegetated swale materials specifications. Table [Link](https://stormwater.pca.state.mn.us/index.php?title=Open_vegetated_swale_and_filter_strip_materials_specifications)

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Specification | Size | Notes |
| Check Dam (pressure treated) | AWPA Standard C6 | 6” by 6” or 8” by 8” | do not coat with creosote; embed at least 3’ into side slopes |
| Check Dam (natural wood) | Black Locust, Red Mulberry, Cedars, Catalpa, White Oak, Chestnut Oak, Black Walnut | 6” to 12” diameter; notch as necessary | do not use the following, as these species have a predisposition towards rot: Ash, Beech, Birch, Elm, Hackberry, Hemlock, Hickories, Maples, Red and Black Oak, Pines, Poplar, Spruce, Sweetgum, Willow |
| Rip rap | per local criteria | size per requirements based on 10- year design flow |  |

* 1. **Design procedure – design steps**
     1. **Step 1. Make a preliminary judgment**

It is important to acknowledge that each site has unique and defining features that require site-specific design and analysis. The guidance provided below is intended to provide the fundamentals for designing swale systems to meet regulatory requirements but is not intended to substitute engineering judgment regarding the validity and feasibility associated with site-specific implementation. Designers need to be familiar with the hydrologic and hydraulic engineering principles that are the foundation of the design and they should also enlist the expertise of qualified individuals in stormwater management and conveyance system plantings with respect to developing appropriate planting plans and habitat improvement features.

* + - 1. ***Consider basic issues for initial suitability screening***

Make a preliminary judgment as to whether site conditions are appropriate for the use of a swale, and identify its function in the overall treatment system.

A. Consider basic issues for initial suitability screening, including:

* Site drainage area
* Site topography and slopes
* Regional or local depth to ground water and bedrock
* The seasonally high water table may inundate the swale; but not above the design bottom of the channel.
* Site location/minimum setbacks.
* Presence of active karst.

B. Determine how the swale will fit into the overall stormwater treatment system, including:

* Decide whether the swale is the only BMP to be employed, or if are there other BMPs addressing some of the treatment requirements.
* Decide where on the site the swale will most likely to be located.
  + 1. **Step 2. Confirm design criteria and applicability**

A. Determine whether a [media filter](https://stormwater.pca.state.mn.us/index.php?title=Glossary#M) must comply with the [MPCA CGP](http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_permit). To determine if permit compliance is required, see [Permit Coverage and Limitations](https://stormwater.pca.state.mn.us/index.php?title=I._PERMIT_COVERAGE_AND_LIMITATIONS#PART_I._PERMIT_COVERAGE_AND_LIMITATIONS).

B. Check with local officials, watershed organizations, and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

* + 1. **Step 3. Perform field verification of site suitability**

See section 2.2.

* + 1. **Step 4. Select design variant based on physical suitability evaluation**

Once the physical suitability evaluation is complete, it is HIGHLY RECOMMENDED that the better site design principles be applied in sizing and locating the wet swale practice(s) on the development site. Given the drainage area, select the appropriate swale practice for the first iteration of the design process.

Note: Information collected during the physical suitability evaluation (see Step 1) should be used to explore the potential for multiple swale practices versus relying on a single facility. Compute watershed runoff values.

* + 1. **Step 5. Compute runoff control volumes and other key design parameters**

Calculate the Water Quality Volume (Vwq), Channel Protection Volume (Vcp), Overbank Flood Protection Volume (Vp10), and the Extreme Flood Volume (Vp100).

If the swale is being designed to meet the requirements of the MPCA Permit, the REQUIRED treatment volume is the water quality volume of 1 inch of runoff from the new impervious surfaces created from the project. If part of the overall Vwq is to be treated by other BMPs, subtract that portion from the Vwq to determine the part of the Vwq to be treated by the swale.

For swales, compute the following design parameters:

A. Calculate the maximum discharge loading per foot of swale width

q = (0.00236/n) · Y · 1.67 · S · 0.5

Where:

q = discharge per foot of length of the swale, from Manning’s equation (cfs/ft);

Y = allowable depth of flow (inches) (3 to 4 inch maximum);

S = slope of swale (percent) (2 to 6 percent); and

n = Manning’s “n” roughness coefficient (use 0.15 for short prairie grass, 0.25 for dense grasses such as bluegrass, buffalo grass, blue grama grass and other native grass mixtures).

B. Use a recommended hydrologic model to compute Qwq

C. Minimum swale length (in feet) = Qwq / q

Where:

Qwq = the water quality peak discharge (cubic feet per second)

* + 1. **Step 6. Compute number of check dams**
* Design to contain entire Vwq.
* Channel slopes up to 1 percent are recommended unless topography necessitates a steeper slope, in which case 6- to 12-inch drop structures can be placed to limit the energy slope to within the recommended 0 to 1 percent range. Energy dissipation will be required below the drops. Spacing between the drops should not be closer than 50 feet. Depth of the Vwq at the downstream end should not exceed 18 inches.
  + 1. **Step 7. Check 2-year and 10-year velocity erosion potential and freeboard**

Check for erosive velocities and modify design as appropriate based on local conveyance regulations. Provide 6 inches of freeboard.

* + 1. **Step 8. Design low flow control at downstream headwalls and checkdams**

Design control to pass Vwq in 48 hours.

* + 1. **Step 9. Design inlets and sediment forebay(s)**

Inlets to swales must be provided with energy dissipaters such as riprap or geotextile reinforcement. Pre-treatment of runoff is typically provided by a sediment forebay located at the inlet.

* + 1. **Step 11. Check volume, peak discharge rates and drawdown time against state, local, and watershed organization requirements (NOTE: steps are iterative)**

Follow the design procedures identified in the [Unified Sizing Criteria](https://stormwater.pca.state.mn.us/index.php?title=Unified_sizing_criteria) section of the Manual to determine the volume control and peak discharge requirements for water quality, recharge (not required), channel protection, overbank flood and extreme storm.

Model the proposed development scenario using a surface water model appropriate for the hydrologic and hydraulic design considerations specific to the site. This includes defining the parameters of the swale practice defined above: ponding elevation and area (defines the ponding volume), filtration rate and method of application (effective filtration area), and outlet structure and/or flow diversion information. The results of this analysis can be used to determine whether or not the proposed design meets the applicable requirements. If not, the design will have to be re-evaluated.

**Warning**: The following items are specifically REQUIRED by the MPCA Permit:

A. Volume: Swale systems shall be sufficient to filter a water quality volume of 1 inch of runoff from the new impervious surfaces created by the project. If this criterion is not met, increase the storage volume of the filtration practice or treat excess water quality volume (Vwq) in an upstream or downstream BMP (see Step 5).

* + 1. **Step 12. Finalize the cross-section and profile design for the project**

#### Grading plan

Develop a grading plan based on the preliminary profile and cross-section typical design.

#### Dimensions

Adjust the preliminary profile dimensions to accommodate site specific concerns/impacts. Minimum design parameters for hydraulic, water quality, and quantity management criteria should be rechecked based on adjustments to the channels to ensure that safe and adequate conveyance is still maintained.

#### Ditch checks

Adjust the preliminary ditch check dimensions to accommodate site specific concerns/impacts. Minimum design parameters for hydraulic, water quality criteria should be rechecked based on adjustments to the channels profile and bank and bed stability to ensure that safe and adequate conveyance is still maintained.

#### Site stabilization

Course woodchips and compost should be used throughout the limit of disturbance for site stabilization. All areas should be seeded and planted as well as blanketed/matted. Jute blanket should be used within the swale bottom and side slopes. Erosion control blanket with biodegradable netting should be used above the side slopes within the floodplain.

#### Excess materials

It is advisable that excess materials, i.e., cobbles and boulders, be placed at the edge of the cross-section for use during the maintenance phase to correct any physical instability as long as the excess materials do not impede flow or create a hazard.

* + 1. **Step 13. Prepare vegetation and landscaping plan**

A landscaping plan for a wet swale should be prepared to indicate how the enhanced swale system will be stabilized and established with vegetation. Landscape design should specify proper species and based on specific site, soils, sun exposure and hydric conditions present along the channel. Further information on plant selection and use can be found in the [Minnesota plant lists](https://stormwater.pca.state.mn.us/index.php?title=Minnesota_plant_lists) section.

* + 1. **Step 14. Prepare operation and maintenance plan**

See [Operation and Maintenance](https://stormwater.pca.state.mn.us/index.php?title=Operation_and_maintenance_of_Infiltration_trench) section for guidance on preparing an O&M plan.

* + 1. **Step 15. Prepare cost estimate**

See [Cost Considerations](https://stormwater.pca.state.mn.us/index.php?title=Cost-benefit_considerations_for_Infiltration_trench) section for guidance on preparing a cost estimate that includes both construction and maintenance costs.

* 1. **References**
  2. **Related pages**

<https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_infiltration>

<https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_green_roofs>

<https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_filtration>

<https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_bioretention>

1. Wet Swale Construction Specifications Page

Wet swale practices can be an important tool for retention and detention of stormwater runoff and treatment of pollutants in stormwater runoff. Because swales incorporate dense vegetation, additional benefits may include cleaner air, carbon sequestration, improved biological habitat, and aesthetic value.

This page provides a discussion of construction specifications for wet swales.

* 1. **Access agreements**

An easement is a legally binding agreement between two parties, and is defined as “a non-possessory right to use and/or enter onto the real property of another without possessing it.“ An easement is required for one party to access, construct, or maintain any feature or infrastructure on the property of another. Easements can be temporary or permanent. For example, temporary easements can be used if limits needed for construction are larger than the permanent easement footprint of constructed features. Having an easement provides a mechanism for enforcement of maintenance agreements to help ensure infiltration practices are maintained and functioning. [See an example access agreement](http://stormwater.pca.state.mn.us/index.php/Example_construction_access_agreement).

* 1. **Construction specifications for swale practices**

Construction of wet swale practice incorporates techniques and steps that may be considered nonstandard. It is recommended that construction specifications include project pretreatment devices, construction sequencing, temporary and permanent erosion control m0easures, excavation and fill, grading, soil decompaction, material specifications, and final stabilization. All of these topics are addressed in further detail below.

Additional specifications for items applicable to swale practices can be found in the [Minnesota Department of Transportation’s (MnDOT) Specifications for Construction](http://www.dot.state.mn.us/pre-letting/spec/). The [current version](http://www.dot.state.mn.us/pre-letting/spec/2016/2016specbook.pdf) of this resource was completed in 2016. Below is a list of MnDOT sections that may be helpful when writing project specifications for infiltration practices.

1717 Air, land and water pollution

2101 Clearing and grubbing

2105 Excavation and embankment

2511 Riprap

2571 Plant installation and establishment

2572 Protection and restoration of vegetation

2573 Storm water management

2574 Soil preparation

2575 Establishing turf and controlling erosion

3149 Granular material

3877 Topsoil material

3878 Sod

3882 Mulch material

3884 Hydraulic erosion control products

3885 Rolled erosion control products

3897 Sediment control log

* + 1. **Pre-construction meeting**

A pre-construction meeting is recommended and should include a walkthrough of the site with the builder/contractor/subcontractor to identify important features of the work and to review and discuss the plans. This is the best time to identify potential issues related to construction methods and sequencing that will affect site protection, erosion and sediment control, and proper installation of the work.

* + 1. **Site protection**
       1. ***Pretreatment***

[Pretreatment](https://stormwater.pca.state.mn.us/index.php?title=Pretreatment) is a required part of infiltration and filtration practices. Pretreatment is needed to protect BMPs from the build-up of trash, gross solids, and particulate matter. When the velocity of stormwater decreases, sediment and solids drop out. If pretreatment is not provided, this process will occur in the BMP, resulting in long-term clogging and poor aesthetics.

**Warning:** The Construction Stormwater general permit states: To prevent clogging of the infiltration or filtration system, the Permittee(s) must use a pretreatment device such as a vegetated filter strip, small sedimentation basin, or water quality inlet (e.g., grit chamber) to settle particulates before the stormwater discharges into the infiltration or filtration system.

* + - 1. ***Temporary erosion and sediment control***

During construction, it is critical to keep sediment out of the wet swale device as much as practicable. As soon as grading is complete, stabilize slopes to reduce erosion of native soils. Protect temporary soil stockpiles from run-on and run-off from adjacent areas and from erosion by wind. Sweep as often as required if sediment is on paved surfaces to prevent transport offsite by tracking and airborne dust. All sediment and erosion control measures must be properly installed and maintained. When sediment build up reaches 1/3 the height of the device, action is required, such as removing the accumulated sediment or installing additional sediment controls downgradient of the original device. Link [here](http://stormwater.pca.state.mn.us/index.php/Construction_stormwater_program) for more information.

* + - 1. ***Compaction prevention***

Preventing and [alleviating compaction](http://stormwater.pca.state.mn.us/index.php/Alleviating_compaction_from_construction_activities) are crucial during construction of wet swale practices, as compaction can inhibit plant growth and root penetration. The wet swale area should be marked with paint and/or stakes to keep construction traffic from traveling in the area.

* + 1. **Inspection and documentation**

Inspections before, during, and after construction are needed to ensure swale practices are built in accordance with the plans and specifications. It is recommended that onsite inspectors are familiar with project plans and specifications to ensure the contractor’s interpretation of the plans are consistent with the designer’s intent. The inspectors should take frequent photos and notes of construction activities and features as work progresses and at all critical points (such as immediately prior to backfilling). They should check dimensions and depths of all installed materials. All materials and products should be verified or tested for conformance with the specifications.

#### Construction checklists

* Biofiltration
* Ditch check
  1. **Construction sequence**
     1. **Step 1 – Site examination and preparation**

It is the responsibility of the contractor to:

* Examine the areas for performing earthwork and determine that conditions are satisfactory to proceed, or to correct all unsatisfactory conditions prior to starting work.
* Arrange to locate, mark, and protect all existing utilities and underground facilities in the areas of work.
* Remove all existing features marked for removal and required earthwork
* Ensure entire contributing drainage area is stabilized prior to construction
  + 1. **Step 2 – Excavation**

#### For wet swales with no infiltration or filter media

Cut the swale area as shown on the plans. Where possible, excavation should be performed with a backhoe and work should be done from the sides and outside the footprint of the swale area to avoid soil compaction. If it is necessary to work in the swale bottom area, only low ground pressure tracked equipment should be allowed to complete the work. Rubber tire equipment should be strictly prohibited within the swale bottom area, unless working from pavement outside of the basin or trench. The contractor should start the work at the far side of the trench or basin and work their way out.

Contractor is to ensure all laws and regulations are followed regarding stability of excavations. This may require shoring, bracing, sloping, or benching. Materials should not be stockpiled near the edge of the excavation. Drainage and control of water in the excavation must also be considered.

* + 1. **Step 3 – Decompaction**

Soil decompaction is required in all wet swale bottom areas. Decompact subsoil with a backhoe ripper attachment or other approved method to a depth of at least 18 inches below subgrade in all locations indicated on the drawings. Also known as soil loosening or soil ripping, this technique has been shown to reduce compaction from construction activities. For more information on alleviating compaction, [link here](http://stormwater.pca.state.mn.us/index.php/Alleviating_compaction_from_construction_activities).

* + 1. **Step 4 – Installation of materials**

Planting media (link here)

* + 1. **Step 5 – Restoration and plantings**

After final grading has been approved, planting or seeding should happen as soon as possible to avoid erosion, sedimentation, and the establishment of weeds. The contractor should notify the designer at least four days in advance of when planting or seeding will occur in advance of delivery of materials to the site to allow for scheduling of site inspections. At least two weeks prior to the planting or seeding dates, any existing weeds should be thoroughly eradicated mechanically or with herbicide within the project area.

**Warning:** It is REQUIRED that the planting or seeding contractor have proven successful experience installing and maintaining projects of similar scope and scale and provide a superintendent that will be onsite during the entire seeding or planting process.

All seed and plants should be shipped and stored with protection from weather or other conditions that would damage the product. All plants and seeds will be inspected by the designer and items that have become wet, moldy, or otherwise damaged in transit or in storage should be rejected. Plants and seed should arrive within 24 hours of delivery. Plants and seed needs to be protected against drying and damage prior to planting.

It is typical for the plant or seeding contractor to guarantee the work for some length of time. The common minimum for herbaceous plantings or sod is 60 days during the growing season. The growing season in central Minnesota is defined as May 1st through October 31st. A one-year guarantee on containerized plants can help to ensure good establishment and decrease weed infestations while maintaining infiltration rates over time through the growth of healthy root systems. Any watering required to keep the plants healthy should be covered under the cost of the warranty period. It is appropriate to require that the contractor provide some form of surety, such as a letter of credit or other security, to the permitting entity for 150 percent of the estimated costs and quantities of all herbaceous plants or seeding for the duration of the 1-year warranty period. Planting and seeding establishment should meet the requirements within [MnDOT Section 2571](http://www.dot.state.mn.us/pre-letting/spec/2016/2016specbook.pdf) (page 478).

**Warning:** Seeding maintenance requires specialized knowledge and experience in plant and weed identification. Ensure a thorough [maintenance plan](http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_stormwater_infiltration_practices) is established prior to construction and that budget has been allocated for at least three full growing seasons and preferable longer. Native seedings can be more difficult than containerized plantings to establish.

* + 1. **Step 6 – Final stabilization and Closeout**

As defined in the NPDES/SDS Construction Stormwater permit, final site stabilization is achieved when all soil disturbing activity is completed and the exposed soils have been stabilized with a vegetative cover with a uniform density of at least 70 percent over the entire site or by equivalent means to prevent soil failure. Simply seeding and mulching is not considered acceptable cover for final stabilization. Final stabilization must consist of an established permanent cover, such as a perennial vegetative cover, concrete, riprap, gravel, rooftops, asphalt, etc

1. Wet Swale Operation and Maintenance Page

The most frequently cited maintenance concern for wet swales is that they provide a breeding ground for mosquitoes. Common operational problems include:

* blockage by debris and vegetation;
* sediment accumulates in the swale, reducing the storage volume;
* slope stabilizing vegetation is lost; and
* invasive plants out-compete native vegetation
  1. **Design phase maintenance**

Implicit in the design guidance is the fact that many design elements of filtering systems can minimize the maintenance burden and maintain pollutant removal efficiency. Key examples include:

* limiting drainage area;
* providing easy site access (*REQUIRED*);
* providing [pretreatment](https://stormwater.pca.state.mn.us/index.php?title=Glossary#P) (*RECOMMENDED*); and
* utilizing native plantings (see [Plants for Stormwater Design](http://www.pca.state.mn.us/publications/manuals/stormwaterplants.html)).

Wet swales can be designed, constructed and maintained to minimize the likelihood of being desirable habitat for mosquito populations. Designs that incorporate constant inflows and outflows, habitat for natural predators, and constant permanent pool elevations limit the conditions typical of mosquito breeding habitat (see section on [mosquito control](https://stormwater.pca.state.mn.us/index.php?title=Mosquito_control_and_stormwater_management)). For more information on design information for wet swales, link here.

* 1. **Construction phase maintenance**

Proper construction methods and sequencing play a significant role in reducing problems with operation and maintenance (O&M).

Inspections during construction are needed to ensure that the wet swale practice is built in accordance with the approved design standards and specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction, to ensure that the contractor’s interpretation of the plan is acceptable to the professional designer. An example construction phase inspection checklist is provided below.

***Wet swale construction inspection checklist.***Link to this table  
To access an Excel version of form (for field use), click here.

| Project: | | |
| --- | --- | --- |
| Location: | | |
| Site Status: | | |
| Date: | | |
| Time: | | |
| Inspector: | | |
| **Construction Sequence** | **Satisfactory / Unsatisfactory** | **Comments** |
| **1. Pre-Construction** | | |
| Pre-construction meeting |  |  |
| Runoff diverted (Note type of bypass) |  |  |
| Facility area cleared |  |  |
| Project benchmark near site |  |  |
| Facility location staked out |  |  |
| Temporary erosion and sediment protection properly installed |  |  |
| **2. Excavation** | | |
| Size and location per plans |  |  |
| Side slopes stable |  |  |
| Lateral slopes completely level |  |  |
| Longitudinal slopes within design range |  |  |
| Groundwater / bedrock verified |  |  |
| Stockpile stabilized with vegetation and/ or silt fence |  |  |
| Verify stockpile is not eroding |  |  |
| **3. Structural Components** | | |
| Pretreatment devices (e.g., filter strip, rock diaphragm) installed per plans |  |  |
| Inlets installed per plans |  |  |
| Outlets installed per plans |  |  |
| Soil bed composition and texture conforms to specifications |  |  |
| **4. Vegetation** | | |
| For native wet swales, plants and materials ordered 6 months prior to construction |  |  |
| For native wet swales, construction planned to allow for adequate planting and establishment of plant community |  |  |
| Complies with planting specs |  |  |
| Topsoil complies with specs in composition and placement |  |  |
| Soil properly stabilized for permanent erosion control |  |  |
| **5. Final Inspection** | | |
| Dimensions per plans |  |  |
| Pre-treatment operational |  |  |
| Inlet/outlet operational |  |  |
| Vegetation established per specifications |  |  |
| Construction generated sediments removed |  |  |
| Contributing drainage area stabilized before flow is diverted to the practice |  |  |
| Comments: | | |
| Actions to be taken: | | |

* 1. **Post-construction operation and maintenance**

Proper maintenance is critical to the successful operation of a wet swale. Without regular maintenance, wet swales can fill in with sediment and lose important vegetation. This can lead to a reduction or elimination of pollutant removal capacity.

**Warning:** A maintenance plan clarifying maintenance responsibility is *REQUIRED*. Effective long-term operation of filtration practices necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Proper maintenance will not only increase the expected lifespan of the facility but will improve aesthetics and property value.

* + 1. **Inspection and maintenance planning**

A maintenance plan clarifying maintenance responsibilities is REQUIRED. Effective long-term operation of wet swales necessitates a dedicated and routine maintenance schedule with clear guidelines and schedules. Proper maintenance will not only increase the expected lifespan of the facility but will improve aesthetics and property value.

Some important post-construction considerations are provided below along with RECOMMENDED maintenance standards.

* A site-specific O&M plan that includes the following considerations should be prepared by the designer prior to putting the stormwater practice into operation:
  + Inspection and routine maintenance checklist (see below)
  + Vegetation maintenance schedule

***Wet swale operation & maintenance checklist.***Link to this **table**  
To access an Excel version of form (for field use), click here.

| Project: | | |
| --- | --- | --- |
| Location: | | |
| Site Status: | | |
| Date: | | |
| Time: | | |
| Inspector: | | |
| **Maintenance Item** | **Satisfactory / Unsatisfactory** | **Comments** |
| **1. Debris Cleanout (Monthly)** | | |
| Contributing areas clean of litter and vegetative debris |  |  |
| Filtration facility clean |  |  |
| Inlets and outlets clear |  |  |
| **2. Vegetation (Monthly)** | | |
| Vegetation maintenance complies with O&M plan |  |  |
| Vegetation meets performance standards (including control of specified invasive species) |  |  |
| No evidence of erosion |  |  |
| Maintenance of adequate water depths for desired wetland plant species |  |  |
| Have sediment accumulations reduced wet swale volume significantly or are plants “choked” with sediment |  |  |
| **3. Inundated Portion of Swale (Monthly)** | | |
| Floating or floatable debris removal required |  |  |
| Visible pollution |  |  |
| Eutrophication level of the wet swale |  |  |
| No evidence of erosion |  |  |
| **4. Sediment Deposition (Annual)** | | |
| Area clean of sediment |  |  |
| Winter accumulation of sand removed each spring |  |  |
| Contributing drainage area stabilized and free of erosion |  |  |
| **5. Outlet/Overflow Spillway (Annual)** | | |
| No evidence of structural deterioration |  |  |
| No evidence of erosion |  |  |
| No evidence of blockage |  |  |
| Good condition, no need for repairs |  |  |
| **6. Other (Monthly)** | | |
| Encroachment on easement area (if applicable) |  |  |
| Complaints from residents (if applicable) |  |  |
| Any public hazards (specify) |  |  |
| Comments: | | |
| Actions to be taken: | | |

* A legally binding and enforceable maintenance agreement should be executed between the practice owner and the local review authority to ensure the following:
  + Sediment should be cleaned out of any sedimentation chamber when it accumulates to a depth equal to ½ the total depth to the outlet, or when greater than 1.5 feet, whichever is less. The sediment chamber outlet devices should be cleaned/repaired when drawdown times exceed 36 hours. Trash and debris should be removed as necessary; and
  + Silt/sediment should be removed from the swale bottom when the accumulation exceeds one inch.
* Adequate access must be provided for inspection, maintenance and landscaping upkeep, including appropriate equipment and vehicles.
* Wet swales generally should not be used as dedicated snow storage areas, but can be with the following considerations.
  + Snow storage should not occur in areas designated as [potential stormwater hotspots for road salt](http://stormwater.pca.state.mn.us/index.php/Potential_stormwater_hotspots#Infiltration_guidance). **NOTE: Chloride will not be attenuated in filtration BMPs such as wet swales.**
  + When used for snow storage, or if used to treat parking lot runoff, the BMP area should be planted with [salt tolerant and non-woody plant species](http://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists).
  + Practices should always be inspected for sand build-up on the surface following the spring melt event.
* General maintenance activities and schedule are provided below.
  + 1. **Summary of typical maintenance regime**

The list below highlights the assumed maintenance regime for a wet swale.

* First year after planting
  + Adequate water is crucial to plant survival and temporary irrigation may be needed unless rainfall is adequate until plants mature
  + Inspect after significant rain events (e.g. ½ inch)
* As needed
  + Prune and weed to maintain appearance
  + Remove trash and debris
  + Mow filter strip/grass channel (if present)
  + Replace vegetation whenever percent cover of acceptable vegetation falls below 90 percent or project specific performance requirements are not met. If vegetation suffers for no apparent reason, consult with horticulturist and/or test soil as needed
* Semi-annually
  + Inspect inflow and pretreatment systems for clogging (off-line systems) and remove any sediment
  + Inspect filter strip/grass channel for erosion or gullying. Sod as necessary
  + Herbaceous vegetation, trees and shrubs should be inspected to evaluate their health and replanted as appropriate to meet project goals
  + Remove any dead or severely diseased vegetation
* Annually in fall
  + Inspect and remove any sediment and debris build-up in pretreatment areas
  + Inspect inflow points and wet swale bottom for buildup of road sand associated with spring melt period, remove as necessary, and replant areas that have been impacted by sand/salt build up
* Annually in spring
  + Cut back and remove previous year’s plant material and remove accumulated leaves if needed (or conduct controlled burn where appropriate)
  1. **Estimated hours to perform maintenance activities**

All estimated hours listed below would be to perform maintenance on a wet swale system approximately 1,000 square feet in size that has adequate pretreatment and where seed and/or live plants have been installed appropriately.

* **Plant Establishment Period (First two years)**
  + Monthly weeding – 12 visits (6 per year) at 1 hour per visit
  + Vegetation replacement – 1 overseeding or replanting effort, 2 hours (assuming 10 percent warrants replacement)
  + Spring cleanup (cut back of previous years vegetation) – 2 cleanups (1 per year) at 2 hours each
  + Erosion, sediment, and pretreatment cleanout – 2 cleanouts (1 per year) at 1 hour each (assuming vacuum truck clean-out of any sump catch basins)
* **Regular Maintenance (After first two years)**
  + Bi-monthly (every other month) weeding – 3 visits per year at 1 hour per visit
  + Vegetation replacement – 1 overseeding or replanting effort per year on average, 1 hour (assuming 5 percent warrants replacement)
  + Spring cleanup (cut back of previous years vegetation) – 1 per year at 2 hours
  + Erosion, sediment, and pretreatment cleanout – 2 hours per year on average (assuming vacuum truck clean-out of any sump catch basins once per year, and at least one bi-yearly (every other year) sediment removal from the bottom of the swale)
  1. **Erosion protection and sediment monitoring, removal, and disposal**

Regular inspection of not only the BMP but also the immediate surrounding catchment area is necessary to ensure a long lifespan of the water quality improvement feature. Erosion should be identified as soon as possible to avoid the contribution of significant sediment to the BMP.

[Pretreatment](https://stormwater.pca.state.mn.us/index.php?title=Pretreatment) devices need to be maintained for long-term functionality of the entire BMP. Accumulated sediment in filter strips, rock diaphragms, water quality sump catch basins, or any pretreatment features will need to be inspected yearly. Timing of cleaning of these features is dependent on their design and sediment storage capabilities. In watersheds with erosion or high sediment loadings, the frequency of clean out will likely be increased. A vacuum truck is typically used for sediment removal. It is possible that any sediment removed from pretreatment devices or from the bottom of a dry swale may contain high levels of pollutants. All sediments, similar to those retrieved from a stormwater pond during dredging, may be subjected to the [MPCA’s guidance for reuse and disposal](https://www.pca.state.mn.us/sites/default/files/wq-strm4-16.pdf).

If a grassed filter strip is used as pretreatment, they should be mowed as frequently as a typical lawn. Native vegetated filter strips can be maintained less frequently, such as once per year (e.g., mow and remove cut material or prescribed burn). Depending on the contributing watershed, grassed BMPs may also need to be swept before mowing. All grassed BMPs should be swept annually with a stiff bristle broom or equal to remove thatch and winter sand. The [University of Minnesota’s Sustainable Urban Landscape Series website](http://www.extension.umn.edu/garden/landscaping/) provides guidance for turf maintenance, including mowing heights.

* 1. **Seeding, planting, and landscaping maintenance**

Plant selection during the design process is essential to limit the amount of maintenance required. It is also critical to identify who will be maintaining the BMP in perpetuity and to design the plantings or seedings accordingly. The decision to install containerized plants or to seed will dictate the appearance of the BMP for years to come. Inundated areas are typically planted with live plant material such as plugs (as opposed to seed); however, it may be feasible to vegetate these areas using seed if the practice is constructed off-line and the seed is able to grow sufficiently prior to inundation. If the BMP is designed to be seeded with an appropriate native plant based seed mix, it is essential the owner have trained staff or the ability to hire specialized management professionals. Seedings can provide plant diversity and dense coverage that helps maintain drawdown rates, but landscape management professionals that have not been trained to identify and appropriately manage weeds within the seeding may inadvertently allow the BMP to become infested and the designed plant diversity be lost. The following are minimum requirements for seed establishment and plant coverage.

* At least 50 percent of specified vegetation cover at end of the first growing season, not including REQUIRED cover crop
* At least 90 percent of specified vegetation cover at end of the third growing season, not including REQUIRED cover crop
* Supplement seeding/plantings to meet project specifications if cover requirements are not met
* Tailor percent coverage requirements to project goals and vegetation. For example, percent cover required for turf after one growing season would likely be 100 percent, whereas it would be lower for other vegetation types.

For information on plant selection, [link here](http://stormwater.pca.state.mn.us/index.php/Minnesota_plant_lists).

For proper nutrient control, swales must not be fertilized unless a soil test from a certified lab indicates nutrient deficiency. If this is the case, apply the minimum rate of appropriate nutrients to provide a suitable environment for vegetation establishment while also minimizing the mobilization (and loss) of nutrients to downstream receiving waters. Irrigation may be needed during establishment, depending on soils, precipitation, and if stormwater flows are kept off-line during establishment.

Weeding is especially important during the plant establishment period, when vegetation cover is not 100 percent yet. Some weeding will always be needed. It is also important to budget for some plant replacement (at least 5 to 10 percent of the original plantings or seedings) during the first few years in case some of the plants or seed that were originally installed don’t become vigorous. It is highly recommended that the install contractor be responsible for a plant warranty period. Typically, plant warranty periods can be 60 days or up to one year from preliminary acceptance through final inspections. If budget allows, installing larger plants (#1 container vs. 4” pot) during construction can decrease replacement rates if properly cared for during the establishment period.

Weeding in years after initial establishment should be targeted and thorough. Total eradication of aggressive weeds at each maintenance visit will ultimately reduce the overall effort required to keep the BMP weed free. Mulch is generally not recommended for use in swales since flowing water typically washes it downstream; however, mulch may be appropriate in planting beds or around individual trees on upper sideslopes and adjacent areas.

Rubbish and trash removal will likely be needed more frequently than in the adjacent landscape. Trash removal is important for prevention of mosquitoes and for the overall appearance of the BMP.

* 1. **Sustainable service life**

The service life of swales depends upon the pollutant of concern.

* + 1. **Infiltration rate service life before clogging**

Infiltration is not a primary function of wet swales.

* + 1. **Nitrogen reduction**

### Wet swales have an internal water storage (i.e., inundation) zone. If this zone is deep enough and flow rates are low enough, soluble nitrogen will be removed through denitrification, a microbially-mediated process that occurs only under anoxic conditions. Denitrification requires organic matter as a carbon source, which is supplied by decaying root matter and mulch. Particulate bound nitrogen in stormwater runoff will typically be removed through sedimentation. Lastly, plants uptake nitrogen since it is essential for plant growth. All of these processes are self-sustaining with routine maintenance, and the nitrogen reduction service life of a wet swale should be very long. In very shallow or high flow wet swales (i.e., oxygenated systems), denitrification is not an important process, and leaching of nitrate is likely. In systems having soils with a high organic matter content, organic nitrogen can be converted to nitrate, resulting in additional loss of nitrogen through leaching ([Liging and Davis](http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_stormwater_infiltration_practices#References), 2014).

* + 1. **Phosphorus reduction**

Phosphorus removal in wet swales is achieved primarily through sorption of phosphorus to trapped sediments. Therefore, it is beneficial to intermittently remove sediment (with its attached phosphorus) from the bottom of wet swales. Sediment should be disposed in an acceptable manner (e.g., landfill).

* + 1. **Heavy metals retention**

Metals are typically retained in wet swale systems (including wet swales) through sedimentation and adsorption processes. Therefore, it is beneficial to intermittently remove sediment (with its attached metals) from the bottom of wet swales. Sediment should be disposed in an acceptable manner (e.g., landfill). Since there are a finite amount of sorption sites for metals in a particular soil/media, there will be a finite service life for the removal of dissolved metals. [Morgan et al.](http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_stormwater_infiltration_practices#References) (2011) investigated cadmium, copper, and zinc removal and retention with batch and column experiments. Using synthetic stormwater at typical stormwater concentrations, they found that 6 inches of filter media composed of 30 percent compost and 70 percent sand will last 95 years until breakthrough (i.e., when the effluent concentration is 10 percent of the influent concentration). They also found that increasing compost from 0 percent to 10 percent more than doubles the expected lifespan for 10 percent breakthrough in 6 inches of filter media for retainage of cadmium and zinc. Using accelerated dosing laboratory experiments, [Hatt et al.](http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_stormwater_infiltration_practices#References) (2011) found that breakthrough of Zn was observed after 2000 pore volumes, but did not observe breakthrough for Cd, Cu, and Pb after 15 years of synthetic stormwater passed through the media. However, concentrations of Cd, Cu, and Pb on soil/media particles exceeded human and/or ecological health levels, which could have an impact on disposal if the soil/media needed replacement. Since the majority of metals retainage occurs in the upper 2 to 4 inches of the soil/media ([Li and Davis](http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_stormwater_infiltration_practices#References), 2008), long-term metals capture may only require rejuvenation of the upper portion of the media. If concentrations of metals in runoff are anticipated to be elevated, wet swale design should include soil amendments as indicated above.

* + 1. **Polycyclic aromatic hydrocarbons (PAHs) reduction**

Accumulation of polycyclic aromatic hydrocarbons (PAHs) in sediments has been found to be so high in some stormwater retention ponds that disposal costs for the dredging spoils were prohibitively high. Research has shown that rain gardens, on the other hand, are “a viable solution for sustainable petroleum hydrocarbon removal from stormwater, and that vegetation can enhance overall performance and stimulate biodegradation.” ([Lefevre](http://stormwater.pca.state.mn.us/index.php/Operation_and_maintenance_of_stormwater_infiltration_practices#References) et al., 2012). Given that wet swales provide some of the same functions as stormwater retention ponds (i.e., inundated portions) and rain gardens (i.e., higher sideslopes), it would be expected they provide some PAH management. However, swales performance in PAH management has not been the focus of any identified studies.

* 1. **Typical maintenance problems and activities**

The following table summarizes common maintenance concerns, suggested actions, and recommended maintenance schedule.

***Typical maintenance problems and activities for dry swales.***Link to this **table**  
To access an Excel version of form (for field use), click here.

|  |  |  |  |
| --- | --- | --- | --- |
| Inspection Focus | Common Maintenance Problems | Maintenance Activity | Recommended Maintenance Schedule |
| Drainage Area | Erosion of catchment area contributing significant amount of sediment | In case of sediment accumulation >1 inch, remove sediment from bottom of swale. Restore original design cross section and re-seed/plant with vegetation as necessary. | Bi‐monthly April through October |
| Pretreatment | Pretreatment screens or sumps reach capacity | Remove sediment and oil/grease from pretreatment devices/structures. | Minimum yearly or as per manufacturer's recommendations |
| Pretreatment | Vegetative filter strip failure | Reduce height of vegetative filter strip that may be limiting in‐flow. Re‐establish vegetation to prevent erosion. Leave practice off‐line until full reestablishment. | Mow grass filter strips monthly. Restore as necessary |
| Site Erosion | Scouring at inlets | Correct earthwork to promote non‐erosive flows that are evenly distributed. | As necessary |
| Site Erosion | Unexpected flow paths into practice | Correct earthwork to eliminate unexpected drainage or created additional stable inlets as necessary. | As necessary |
| Vegetation | Severe weed establishment | Limit the ability for noxious weed establishment by properly mowing, mulching (if appropriate), or timely herbicide or hand weeding. Refer to the [MDA Noxious Weed List](http://www.mda.state.mn.us/plants/pestmanagement/weedcontrol/noxiouslist.aspx). | Bi‐monthly April through October |
| Vegetation | Vegetative cover | Add seed/plants to maintain ≥95% vegetative cover. | Bi‐monthly April through October |

* 1. **Maintenance agreements**

A Maintenance Agreement is a legally binding agreement between two parties, and is defined as ”a nonpossessory right to use and/or enter onto the real property of another without possessing it.“ Maintenance Agreements are often required for the issuance of a permit for construction of a stormwater management feature and are written and approved by legal counsel. Maintenance Agreements are often similar to Construction Easements. A Maintenance Agreement is required for one party to define and enforce maintenance by another party. The Agreement also defines site access and maintenance of any features or infrastructure if the property owner fails to perform the required maintenance.

Maintenance Agreements are commonly established for a defined period such as five years for a residential site or 10 to 20 years for a commercial/governmental site after construction of the filtration practice. Maintenance agreements often define the types of inspection and maintenance that would be required for that filtration practice and what the timing and duration of the inspections and maintenance may be. Essential inspection and maintenance activities include but are not limited to sediment removal, erosion monitoring and correction, and vegetative maintenance and weeding. If maintenance is required to be performed due to failure of the site owner to properly maintain the filtration practices, payment or reimbursement terms of the maintenance work are defined in the Agreement. Below is an example list of maintenance standards from an actual Maintenance Agreement.

1. Live plantings and seeding areas shall be watered as necessary to achieve performance standards.
2. Weeding and vegetation management (e.g., mowing, spot spraying) shall be conducted as necessary to achieve performance standards.
3. Dead plant material, garbage, and other debris shall be removed from the swale at least annually.
4. Silt/sediment should be removed from the swale bottom when the accumulation exceeds one inch.
5. Side slopes must be inspected for erosion and the formation of rills or gullies at least annually, and erosion problems must be corrected immediately.
6. If properly planned, designed, constructed, and maintained (including protected from sediment and compaction and incorporating sufficient pretreatment), a wet swale is likely to retain its effectiveness for well over 20 years. After that time, inspection will reveal whether interventions are warranted.

In some project areas, a drainage easement may be required. Having an easement provides a mechanism for enforcement of maintenance agreements to help ensure swales are maintained and functioning. Drainage easements also require that the land use not be altered in the future. Drainage easements exist in perpetuity and are required property deed amendment to be passed down to all future property owners.

As defined by the Maintenance Agreement, the landowner should agree to provide notification immediately upon any change of the legal status or ownership of the property. Copies of all duly executed property transfer documents should be submitted as soon as a property transfer is made final.

* [Example Maintenance Agreement 1](https://stormwater.pca.state.mn.us/index.php?title=Example_Maintenance_Agreement_1)
* [Example Maintenance Agreement 2](https://stormwater.pca.state.mn.us/index.php?title=Example_Maintenance_Agreement_2)
* [Example Maintenance Agreement 3](https://stormwater.pca.state.mn.us/index.php?title=Example_Maintenance_Agreement_3)
  1. **Maintenance inspection reports**
* [Maintenance inspection report for dry swale](https://stormwater.pca.state.mn.us/index.php?title=Maintenance_inspection_report_for_dry_swale_with_check_dams" \o "Maintenance inspection report for dry swale with check dams) (see below)

**Wet Swale**

**Maintenance Inspection Report**

Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Inspector Name/Address/Phone Number: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Site Address: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Owner Name/Address/Phone Number: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Drainage Area Stabilization (Inspect after large storms for first two years, Inspect yearly in spring or after large storms after first two years)**

* Erosion control/planting/seeding necessary: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Mowing, pruning and debris removal necessary: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Observations:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Inlets & Pre-Treatment Structures (Inspect in Spring and Fall)**

* Repair needed: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Debris & sediment removal required: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Erosion evident: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Water by-passing inlet: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Vegetation control necessary: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Observations:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Swale (Inspect after large storms for first two years, Inspect yearly in spring or after large storms after first two years)**

* Condition of inundated area: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Surface erosion evident: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Debris/sediment removal required: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Weeding and pruning necessary: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Observations:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Outlet/Emergency Overflow (Inspect in Spring and Fall)**

* Overflow type: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Debris/sediment removal required: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Repair needed: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Observations:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Link to [Chesapeake Stormwater visual indicators form](http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/06/Visual-Indicators-Form.pdf).

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